



Commissioning MMS 3/7/16

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the public through innovative science
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Agenda



- **MMS Overview**
- **Diversity as a Problem**
- **Solutions for MMS Commissioning**
- **Results**
- **Lessons Learned**

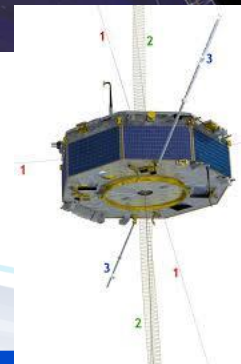
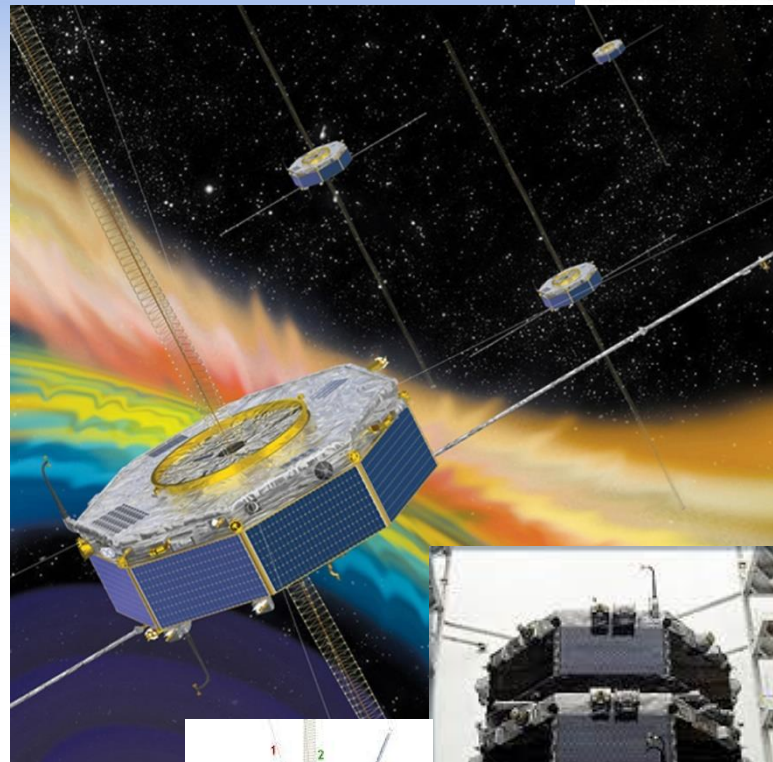




Magnetospheric Multiscale (MMS) Overview



- Investigate magnetic reconnection in boundary layer of Earth's magnetosphere
- Examine magnetic and electric fields, 3D particle distribution functions, and plasma waves
- Four spin stabilized observatories in 10 to 400 km tetrahedral spacing
- Two orbit phases: 1.2×12 Re and 1.2×25 Re



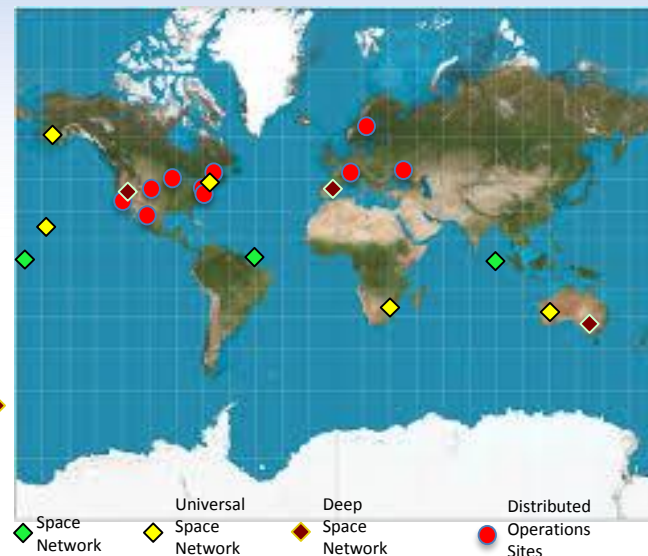




Problem: MMS Diversity



- Four 3mx1m observatories (3 more than most other missions)
- 26 sensors, including 8 booms, per observatory, with diverse objectives and constraints
- >10 geographically distributed science and mission operations ●
- Three different ground software systems
- Three distinct communication and tracking networks with new methods ◆◆◆
- Spinning observatories requiring precise translational control, multiple maneuver types and control modes



300 unique activities per observatory to execute in 5 months





Scope of Commissioning



Per Observatory

Sensor	# of Activities	Total Duration	Realtime Duration
CIDP	36	31:20:00	31:20:00
ASPOC	128	0:00:00	200:23:20
EIS	36	44:56:00	59:08:00
FEEPS	20	17:04:00	12:00:00
FIELDS	107	279:29:00	215:20:00
FIELDS/EDI	164	152:00:00	152:00:00
FPI	78	154:30:00	106:30:00
HPCA	42	104:18:00	103:33:00
IS	13	130:00:00	130:00:00
SC	224	831:38:00	84:18:00
TOTAL	848	1745:15:00	1094:32:20
SC#1	207	441:04:30	220:02:20
SC#2	207	442:54:30	223:52:20
SC#3	205	438:54:30	219:52:20
SC#4	205	438:54:30	219:52:20
SC-ALL	24	323:47:00	130:45:00

Activity Type	Number
Low Voltage (LV)	16
High Voltage (HV)	64
Deployments	14
Instrument Suite Level (IS)	13
Care and Feeding	18

Activity Type	Number
Powering the CIDP and IS	6
Table and Real Time Sequence Loads	5
Oscillator and Clock Configuration	3
Navigation Hardware and Software	4
ACS Sensors & Calibration	9
RF Communications	13
Thermal & Power	10

32 Maneuvers per Observatory





Solution Approach



Extensive pre-launch planning involving representatives from all operations communities, including each science sensor

Science Working Team; dedicated Commissioning Splinters; Burn Operations Group to define maneuver interfaces, operations, and expected results; bi-weekly telecons; Technical Interchange Meetings with each of the three networks

- **Established rules for scheduling: human resource; network patterns for communication and tracking; science constraints; spacecraft bus constraints; flight dynamics; contingency mitigation and resolution**
- **Clearly defined roles and participation for each operational team**
- **Developed 3 levels of planning cycle with established daily rhythm:**
 - Strategic: 2 weeks to several months
 - Tactical: Next orbit to 2 weeks
 - Real Time: Upcoming contacts
- **Thread tests for subsystems, borrowing from integration test-as-you-fly scenarios**
- **Rehearsals dedicated to commissioning activities**
 - Standalone instrument sensors
 - Integrated observatory, executed in real-time across two different heavily loaded periods with anomalies
- **Dedicated Commissioning Review with all operations communities**
- **Cross-team training on instruments among all operations communities**
- **Tools to capture and validate constraints**



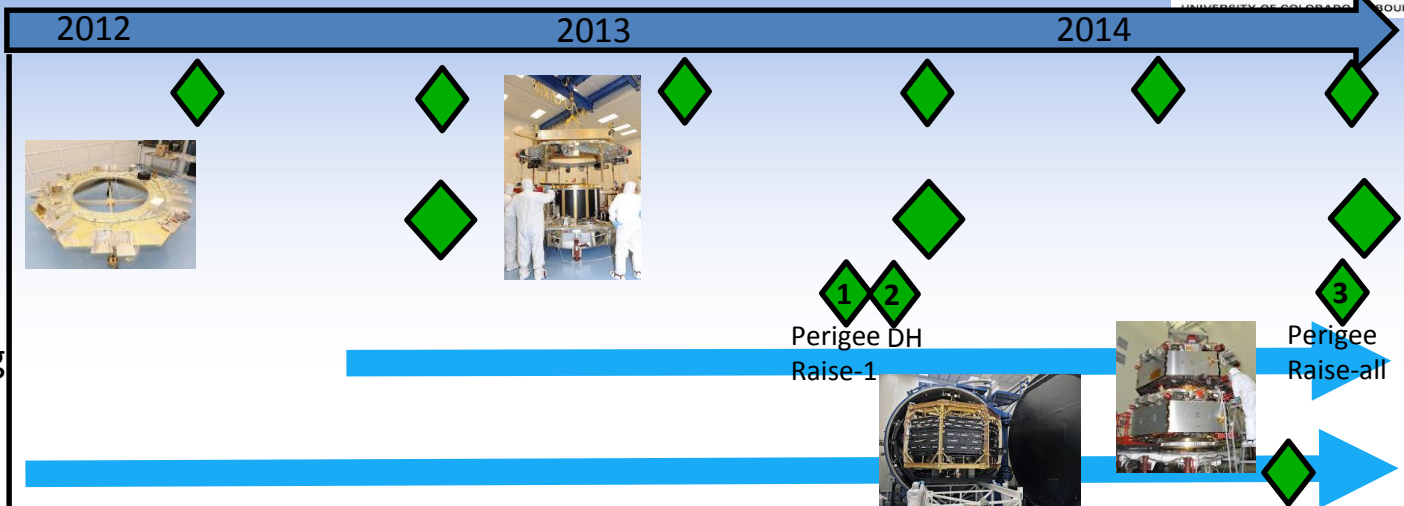


Solution: Pre-Launch Planning



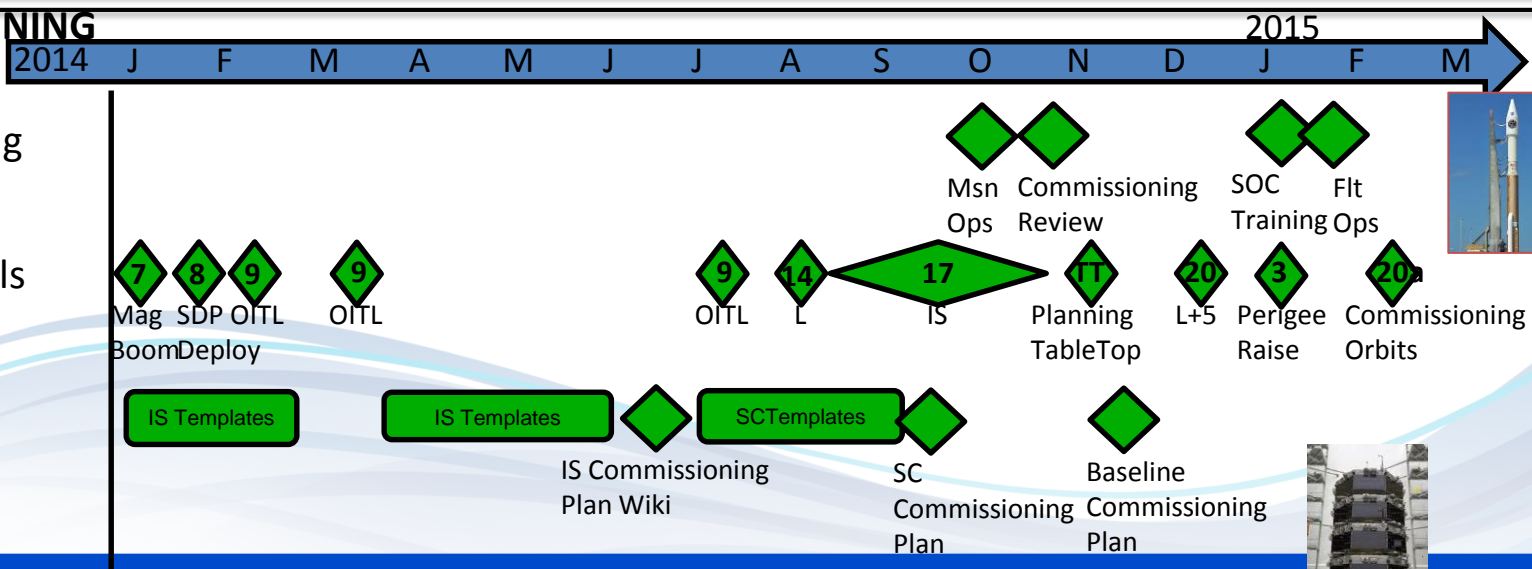
LONG TERM PLANNING

- Science Working Team Meetings
- Commissioning Splinters
- Mission Rehearsals
- Biweekly Commissioning Telecons
- Burn Operations Group



NEAR TERM PLANNING

- Reviews & Training
- Mission Rehearsals
- Documentation

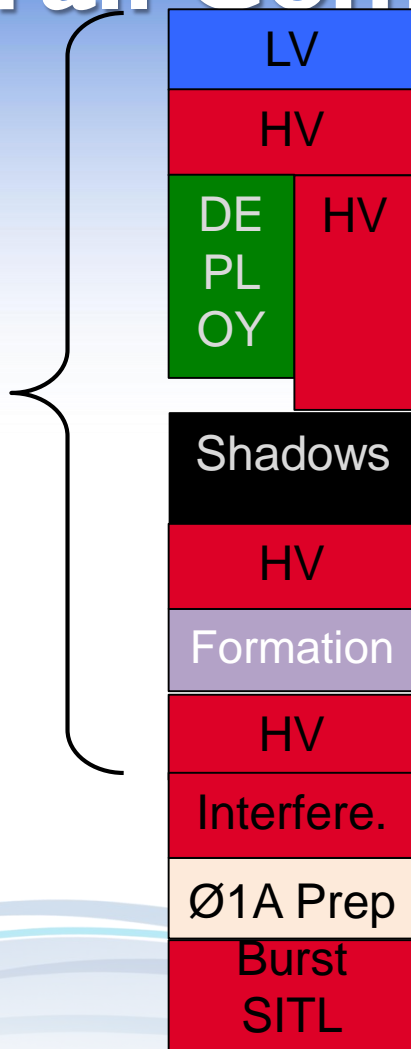




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Results: Overall Commissioning Plan

Activation



Ø1A

MNVRs

S/C: ACS, NAV,
COMM, THRML, PROP

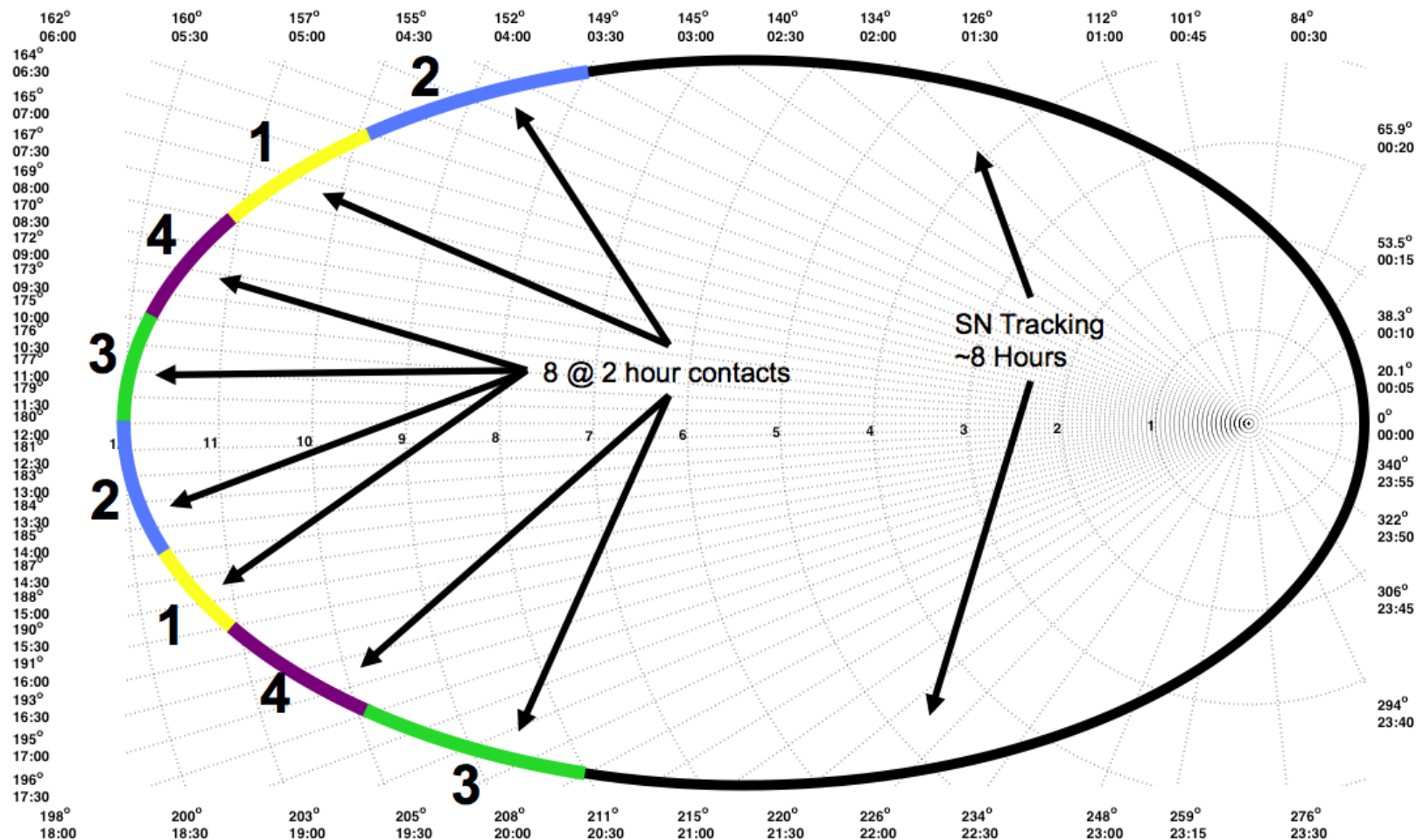
MNVRs

Shadows

T
I
M
E



Results: Typical DSN Contact Pattern: Early Period Orbits

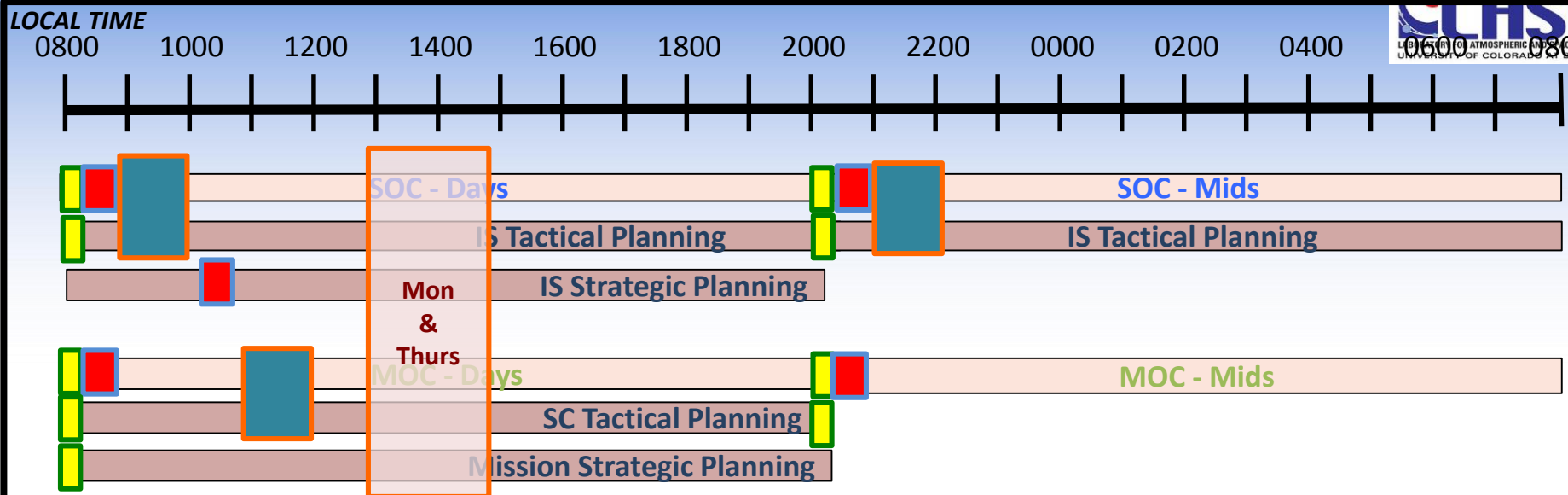


- 2 @ 2 hour contacts on each spacecraft separated by 8 hours
- Descending order starting w MMS-2: 2-1-4-3-2-1-4-3 order centered on apogee





Results: Commissioning Planning Daily Rhythm

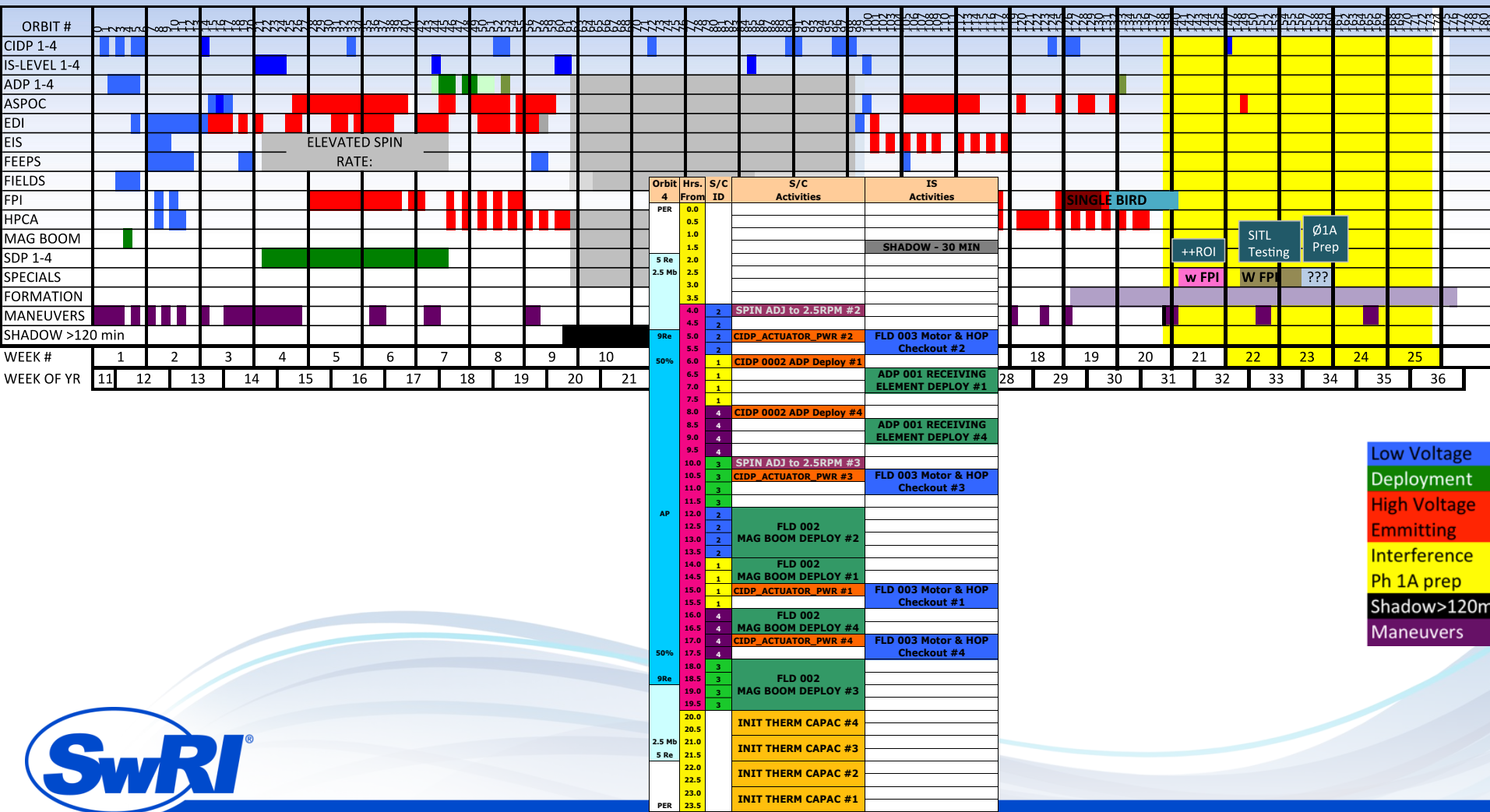


- Shift Handover (~15 min)** – previous shift accomplishments, incompletes & reason, activities for next shift (include ‘awareness items’); delegate to report to Commissioning Planning Team, provide inputs to Checklist.
- Operations Pre-Activity Review (~30 min)** – Review activities completed, Anomaly Reports, Change Requests, planned shift activities and constraints
- Tactical Planning Meeting (~1 hr)** – Review completed activities, new Anomaly Reports, Change Requests, ground status reports; establish tactical plan
- Strategic Planning Meeting (~1-2 hr, Mon & Thurs)** – Review completed activities against the 2-week plan, review Anomaly Reports, Change Requests; coordinate among all entities involved; establish next 14-orbit plan and EoC plan.





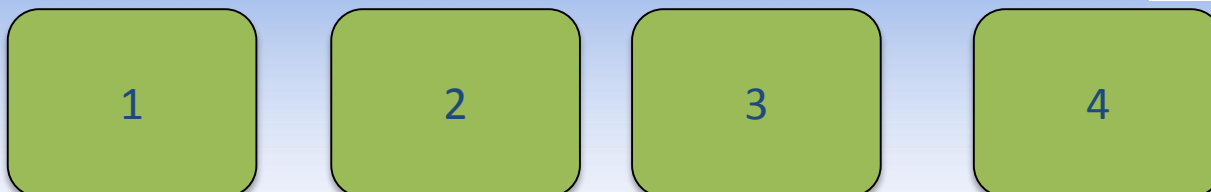
Results: Commissioning Campaign



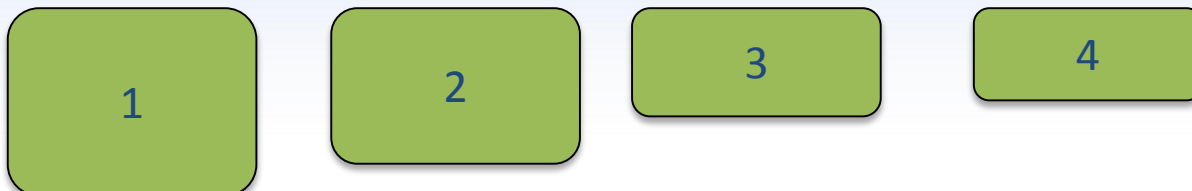


Lesson Learned: Multiple Spacecraft as Production

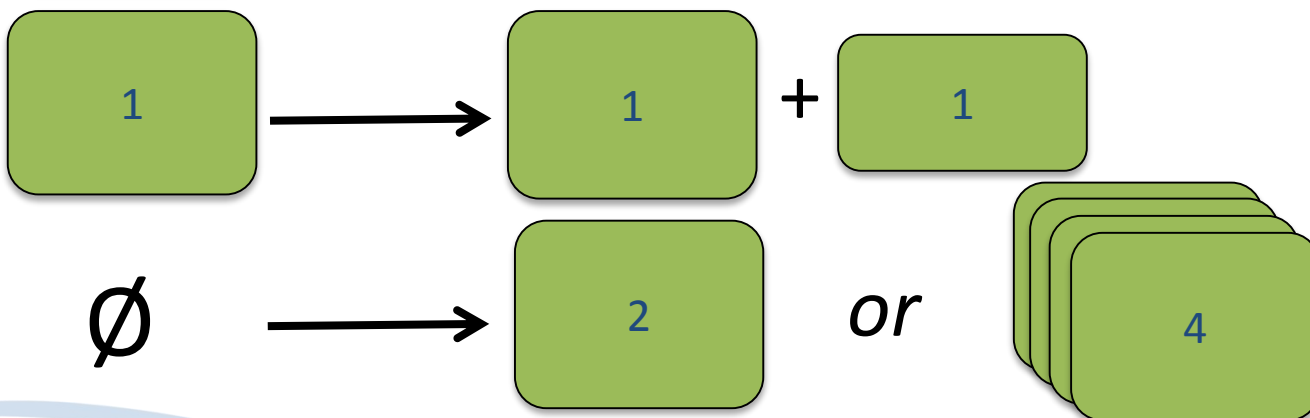
Original: Equal
time for each
spacecraft



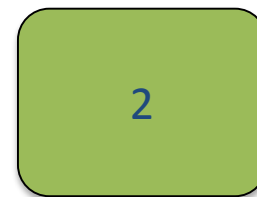
Practice makes
perfect: << time



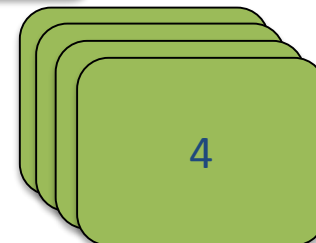
Increased
execution time or
overhead due to
split contacts



New Activities



or



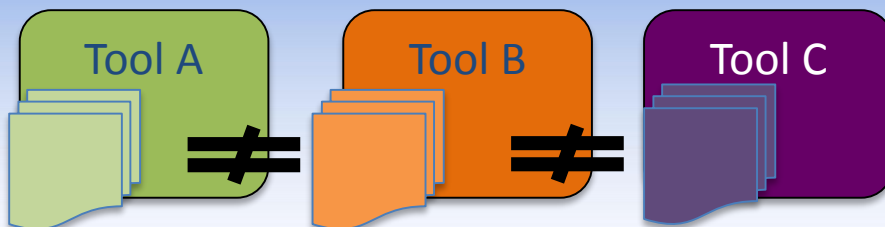
Lesson Learned: Budget and schedule execution time conservatively, but embrace flexibility to take advantage of opportunities.



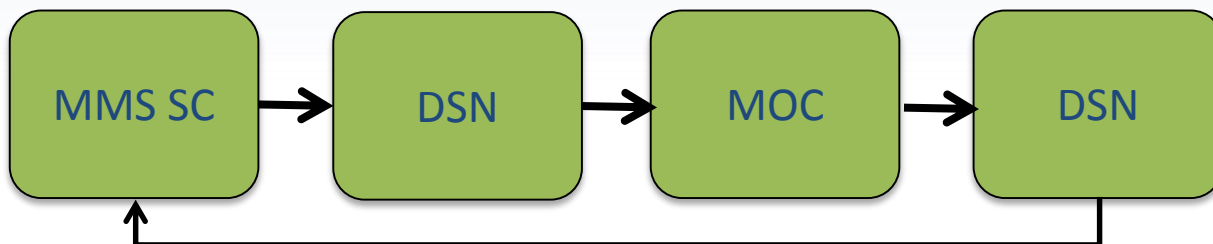
Lesson Learned: Test As You Fly



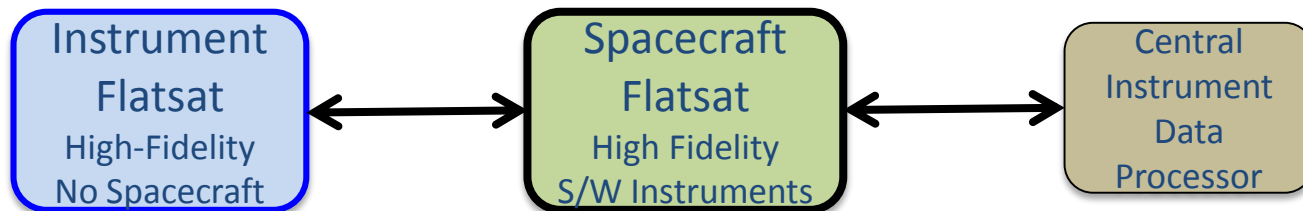
**Diverse Ground
Command and
Telemetry
Systems**



**Understanding
& Modeling
System Delays**



**Missing Full Fidelity
Observatory
Simulator**



Lessons Learned: Standardize ground segment tools &/or scripting prior to I&T; Model system critical path delays; Provide high fidelity end-to-end simulation.





Lesson Learned: Complexity vs Flexibility



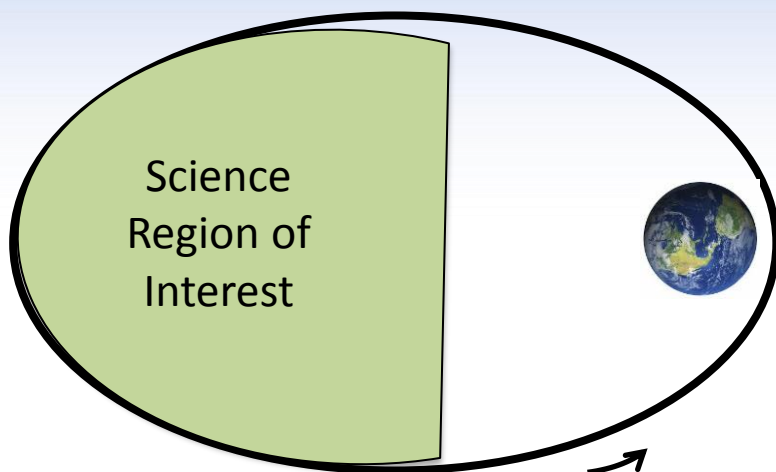
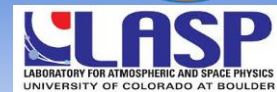
- **Some contacts reserved for commissioning were not able to be filled due to last minute developments**
 - Not enough candidate activities were always ready
 - Lead time for new activities could be high
 - Complexity in scheduling became unmanageable (equipment safety, human factors, ATS planning, etc.)
- **Fortunately, the planned schedule had adequate time built in such that the end date for commissioning was maintained**



Lessons Learned: Complexity in spacecraft and limitations in infrastructure often precludes flexibility and results in inefficiencies.



Lesson Learned: Team Shift Scheduling



Science Operations followed the orbit,
with shift changes at apogee and perigee.



Mission Operations followed Day/Night shift,
except maneuvers and special activities.



Lessons Learned: Shift schedules can differ and be based on the S/C operations priorities while maintaining an effective daily rhythm.



MMS Commissioning Summary



- Four precision spinning spacecraft with 26 sensors and over 30 maneuvers presents a complex challenging commissioning effort.
- Careful planning was essential in managing the effort.
- The complexity, constraints, and schedule precluded a degree of flexibility.

MMS commissioning was successfully executed on time!